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Commercial Cole Crop Production in Alberta
(cabbage, cauliflower, broccoli, Brussels sprouts)

The term cole crops is commonly used to designate vegetables that belong to the mustard (cruciferous) family and include cabbage, cauliflower, broccoli and Brussels sprouts. Cole crops are best suited to a cool climate and this characteristic allows production of cole crops in most areas of the province. All four crops are grown in Alberta with cabbage and cauliflower making up the majority of the commercial acreage in the province.

The production recommendations that follow are very similar for all four crops. When special cultural practices apply, they will be dealt with in detail separately under each crop.

Varieties

Variety recommendations may vary from year to year, therefore reference should be made to the current issue of the Alberta Vegetable Production Guide. Market requirements for each crop also vary and some varieties fulfill these requirements better than others do. Variety trials are conducted at Alberta Agriculture research centers in Brooks and Edmonton for the benefit of producers. Results are published and made available to producers every year. Consult with the vegetable specialists at these institutions before making seed purchases.

Cabbage

Cabbage types are classified into three categories based on the number of days to maturity: early, mid-season and late. It is the duration of growth that generally influences head size the most. A long period of growth also produces more leaves and this generally results in a larger and more dense head. Based on these rough observations, each variety fits into a specific category.

Early cabbage varieties are characterized by a noticeably smaller and softer head that has a high tendency to split. In a short period of time these varieties deteriorate in color, which is often noticeable soon after harvest. These varieties must be marketed quickly. In recent years, the trend has been toward earlier and earlier marketing, which largely has been achieved through the use of transplants. Many varieties fulfill the earliness requirement, but are unsuitable because their heads are too small and soft. The Wholesale market requires a head that measures at least 15 cm (6 in.) in diameter and weighs about 1.5 kg (3 to 4 lb).

Mid-season varieties are both larger in head size and also heavier than early varieties. Many of the best sauerkraut varieties fit in this category. Mid-season cabbage has a much less frequency of splitting because water content in leaves is considerably less than in early maturing varieties and this allows the producer to hold the crop in the field if the market is slow. Like early varieties, mid-season varieties do not store well. Quality, particularly color, deteriorates soon after harvest.

Storage cabbage varieties require a very long growing season to mature and in some parts of the province transplants rather than direct seeding is required to ensure crop maturity. The exposure to frost results in little or no damage to a maturing crop because this category of varieties has the lowest water content and highest fibre development. These two characteristics also give these varieties the ability to resist head splitting. A side benefit to frost exposure is that the cabbage sweetens considerably because a cold snap induces starch stored in the leaves to change to sugar. Winter cabbage varieties are known to withstand temperatures of -10° C and still remain marketable if handled properly. Color retention in winter varieties is a critical selection criterion. Recommended varieties have the ability to retain good green color in excess of six months in storage. Some more recent introductions also have genetic traits that give resistance to damage from thrips.

Cauliflower

Among cauliflower varieties, there is no clear classification distinction based on the number of days to maturity. Generally, early maturing varieties produce fewer and smaller leaves, which results in production of poorer quality curds. Buttoning (producing curd) too early before sufficient numbers of leaves have developed, is a characteristic of unsuited early varieties that have poor tolerance to

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cold temperatures. Later maturing varieties produce more leaves that are larger in size and consequently have larger and heavier heads. Later maturing varieties generally produce the best quality curds. Breeding efforts have been directed at developing good self-wrapping characteristics and tolerance to heat. Unfortunately, heat resistance seems to have come at the expense of cold tolerance. New varieties from Holland and England are very cold tolerant, resisting temperatures below 10° C and still producing a normal curd. The shortcoming of these new varieties is that head development is delayed if high temperatures prevail during the growing season and this is a problem in southern Alberta with mid-summer crops.

Broccoli

Like winter cabbage, broccoli is very tolerant to freezing temperatures, particularly as a mature plant. Varieties are not classified on the basis of number of days to maturity, but rather stem production habit. The best commercial varieties produce one dominant stem that is suitable for once-over harvesting. Multi-stem varieties distribute growth among several smaller stems that mature in close succession. These varieties are ideal for market gardeners. Good commercial varieties produce a large head that is high on the stem and clear of leaves, which may cover the head and complicate harvest. Heads must be free of leaves and have a strong stem with no visible internal cracks or hollow stem. Hollow stem occurs mostly as a result of cultural practices.

Brussels Sprouts

Only the earliest varieties are recommended because Brussels spourts require a very long growing season. Taller stemmed varieties tend to be late maturing. Good varieties produce sprouts that are well spaced on the stem and size up uniformly. This crop is difficult to grow and no one variety makes the task any easier.

Soil Requirements

Cole crops prefer a heavily textured soil that holds moisture and in which high moisture levels are more easily maintained. A well-drained soil is also required because cole crops require fairly heavy water applications and pools of free standing water can quickly develop if a subsurface hardpan layer exists.

Land previously cropped in canola or mustard should be avoided. Volunteer seedlings of these cruciferous crops cannot be controlled by the herbicides registered for use in cole crops. Check the current issue of the Alberta Vegetable Production Guide for registered herbicides. For the same reason, land infested with stinkweed should be avoided. Close proximity to a canola or mustard field can also create a severe problem with flea beetles, a small chewing insect that damages all cruciferous crops.

A 3 to 4 year crop rotation is recommended to prevent serious disease problems from occurring. In recent years, some producers have continued to grow cole crops for 4 to 6 years consecutively and no problems have been encountered. If using this cropping technique, plow down all crop residue in the fall and monitor soil nutrient levels closely.

Fertilizer

Cole crops have a high requirement for nitrogen and phosphorus. Although no specific field trials have identified the exact nutrient needs, the following should be used as a guide: 70 to 90 kg/ac nitrogen, 35 to 70 kg/ac phosphorus and 90 to 140 kg/ac potassium, should be available at the beginning of the growing season.

Some major nutrients strongly influence the quality of cole crops and the producer should be aware of crop response to excesses and deficiencies of these nutrients (see the following).

Cabbage

Generally, the yield of cabbage increases with higher nitrogen application. The unfortunate result is that the quality of cabbage decreases through a lowering of per cent dry weight. Consequently, heads have an elevated water content and a greater tendency to split, and tipburn is also more noticeable. This can be a real problem with early maturing varieties which have a tendency to split due to their genetic make-up. For storage varieties, excessive levels of nitrogen can be even more devastating because of delayed maturity and reduced storage quality. It is important to remember that excessive levels of nitrogen should be balanced-off with higher levels of phosphorus to improve quality in cabbage. Avoid late summer applications of nitrogen.

Cauliflower

Production of cauliflower is improved by split applications of nitrogen. Only one-half of the required nitrogen should be applied before 30 per cent of the growing period has passed. Split nitrogen applications have shown that absorption of both phosphorus and potassium is increased and quality is improved. As in cabbage, a good balance between nitrogen and phosphorus improves cauliflower quality. An excessive level of applied nitrogen produces more and larger leaves. The leaves are required to blanch the curd, however, maturity is delayed particularly when phosphorus levels do not

balance with nitrogen and excessive levels of nitrogen stimulate leaf growth at the expense of curd initiation.

Broccoli

The incidence of hollow stem in broccoli increases in the presence of high nitrogen levels. Hollow stems are undesirable in a crop destined for commercial marketing. Tenderness and lack of fibre development in stems improves with nitrogen application, so a good balance is required with phosphorus to reduce the incidence of hollow stem.

Brussels Sprouts

Because Brussels sprouts require such a long growing season, split nitrogen applications are part of good production management. One-half of the required nitrogen should be held and applied only after mid-July when plants are growing most actively.

Direct Seeding

From a cost point-of-view, direct seeding is a less expensive way to establish cole crops in the field. This is true provided a precision drill is used and the weed infestation level is manageable. The Stanhay Mark II precision drill is most commonly used. It is a belt seeder that if properly operated, can plant a stand where little or no thinning is required. A smooth rubber seed belt is usually cut to a single line of 36 holes that spaces seed anywhere from 8 to 15 cm (3 to 6 in.) apart in the row. When a precision drill is used, all seed must be graded to be of uniform size so each hole cut in the seed belt drops only one seed.

The first seeding can take place from mid-April and onwards. Successive seedings at predetermined time intervals can be used to supply a continuous harvest in such crops as broccoli and cauliflower. The seed is usually drilled into the soil at a 1 cm (½ in.) depth. Shallow seedings require surface soil moisture to activate seed germination otherwise; early spring and successive seedings lose their advantage.

Transplanting

The use of transplants in cole crop production is becoming more popular. Producers prefer transplants because they allow for more uniform harvest and earlier access to markets. Greater detail on production of transplants is given in the current issue of the Alberta Vegetable Production Guide. Transplants require 5 weeks in the greenhouse to grow to a sufficient size for field transplanting. Plugs have become increasingly popular and mechanical transplanting equipment has been developed to plant the seedlings in the field. Generally plug size rather than plug type has the greatest effect on the yield of cole crops; yield increases with increases in plug size. Due largely to greenhouse economics, the 128 plug tray works the best. A 200 plug tray results in a smaller plant and some transplanting equipment does not do a good field planting operation with the small plugs.

Each season, transplants are field planted earlier and earlier. Properly hardened plants that have been in the field for a few days before frost occurs have a better survival record than do recently set plants. Frosts of -2° C can be tolerated. A prolonged period of temperatures below 7° C will cause cauliflower to button (head out) early. With early field transplanting, water becomes necessary to establish plants in the field and if properly applied, water has some value in preventing frost damage.

Many producers combine direct seeding and transplanting with the objective of producing a continuous harvest for market. Scheduling in such a case becomes complicated and often fails to meet that objective. Failure is mostly attributed to environmental influences that are beyond the control of the producer (see special problems). The following table presents data on the number of days required from direct seeding and transplanting of cole crops at Edmonton and Brooks locations.

Table 1. Approximate number of days required from direct seeding and transplanting of cole crops to produce the first harvest.

Crop	Planting Method		Number Day Required	
	Direct Seed	Transplant	Edmonton	Brooks
Cabbage - early	*		90-105	80- 95
mid-season	*		110-140	100-120
late	*		150+	130+
early		*	60- 80	55- 65
mid-season		*	80-100	70- 90
late		*	120+	100+
Cauliflower	*		100-130	90-120
		*	70- 90	60- 80
Broccoli	*		75- 85	80-100
		*	60- 90	50- 70
Brussels Sprouts		*	120+	100+

Weed and Insect Control

Current pesticide recommendations are given in the Alberta Vegetable Production Guide.

Most problem weeds are members of the cruciferous family to which cole crops belong. Volunteer canola, mustard and stinkweed cannot be controlled by herbicides registered for use in cole crops. A good crop rotation will not include canola or mustard and even close proximity to these crops should be avoided.

Insect pests common to canola and mustard also infest cole crops, therefore close proximity to fields of canola and mustard is not recommended. Problem insects include flea beetles and root maggots. Flea beetles attack emerging seedlings and are more active during hot, dry weather. These persistent insects are best controlled by applications of registered insecticides every 3 to 4 days. Flea beetle infestations become particularly severe in cole crops when canola and mustard crops are senescing and being swathed. Flea beetles move out in large numbers looking for succulent cole crop seedlings. Root maggot infestations are higher in organic soils and on sites where canola or mustard have been part of the crop rotation. Another problem pest of cole crops is the cabbage worm. The cabbage worm is effectively controlled by several registered insecticides of which some do not leave a residue. The advantage of non-residual insecticides is that no waiting period is required after application and before harvest can take place.

Irrigation

Cole crops require about 400 to 500 mm (16 to 20 in.) of moisture during the growing season; late cabbage varieties and Brussels sprouts may require up to 600 mm (24 in.). All cole crops dislike high temperatures. Frequent light or moderate water applications will provide a beneficial cooling effect. Early cabbage varieties in particular should not be irrigated heavily after their heads begin to approach maturity because severe splitting of heads will likely result.

Special Problems

Cabbage Plant Population

Place spacing is one of the principle factors that influence cabbage head size. Trials in Alberta have shown that there is a direct increase in overall yield as spacing between plants is reduced. The yield increase is directly attributed to a greater number of plants per acre. Along with the yield increase, head size and weight decrease. These smaller heads are less subject to splitting regardless of variety. Furthermore, as plant density increases, the distance from soil surface to base of head increases, maturity is delayed and the incidence of pest damage rises.

Field accessability by equipment is a major factor that determines the spacing a cabbage producer will use. Taking this into consideration and also plant physiological response to population pressures, the following spacings are recommended:

75 cm (30 in.) between rows, 38 cm (15 in.) between plants - 14,500 plants/acre
75 cm (30 in.) between rows, 45 cm (18 in.) between plants - 11,600 plants/acre

Cauliflower Plant Population

The response to plant population of cauliflower differs from one cultivar to another, however, some common observations have been noted among varieties tested in Alberta. Generally, head size decreases with closer spacing between plants and this results in an overall yield increase attributable to the greater number of plants per acre. Uniformity of maturity improves with higher plant density, however, quality deteriorates because of looseness and irregularity in head shape. Maturity is also delayed, a response a producer can not afford when attempting to schedule successive crops for a continuous harvest.

Field accessability by equipment dictates spacing between rows. Considering this factor and previously discussed physiological responses, the following are recommended:

75 cm (30 in.) between rows, 38 cm (15 in.) between plants - 14,500 plants/acre
75 cm (30 in.) between rows, 45 cm (18 in.) between plants - 11,600 plants/acre

Curd Initiation and Growth in Cauliflower

To maintain continuous cauliflower production throughout the season, the producer must direct seed/transplant several times. In spite of planting at regular intervals, the number of cauliflowers ready for harvesting often shows great variation. This unpredictable nature in cauliflower is a problem when supplies are guaranteed for market and when hiring harvest labor. The variability in the number of cauliflowers to be harvested weekly is mainly caused by a variation in the length of the growing period required for the different plantings.

Why does this variation in time to maturity occur? The simple answer is the variability in summer temperatures both from week to week and year to year. Temperature influences the growth of cauliflower in two ways:

- by affecting the time of curd initiation (when a curd is formed)
- by affecting the rate of curd growth.

Before curd initiation, there is a period of vegetative growth, which varies in duration according to genetic

makeup and environmental conditions. This period comprises two distinct phases:a juvenile phase when curd initiation is not possible, followed by a mature or "inductive" phase when it is. Clearly, therefore, accurate prediction of development in cauliflower and efficient manipulation of curd initiation can only be achieved if juvenility (vegetative phase) and the factors that affect it could be defined.

It has recently been shown that cauliflower needs to accumulate "relative cold" before it can change from the vegetative phase of producing leaves to forming the curd. The optimum "relative cold" temperature range varies with the variety and is known to fall betweeen 5 and 18°C. If temperatures are lower or higher than the optimum, the "relative cold" treatment takes longer and curd initiation is delayed. In this way, a sequence of crops may not initiate curds at the planned time and thereby disrupt the harvest schedule. Because mean temperature accumulation alone does not clearly mark the end of the juvenile or vegetative stage, leaf number is also being investigated to predict maturity. The curd initiation date can be predicted by using mean temperature accumulation combined with leaf number during growth. The complicating aspect is that for each variety temperature accumulation measure and leaf number varies. This prediction technique is yet to be proven of value to the cauliflower producer.

What further complicates the issue is that temperatures after curd initiation affect the time of maturity because the curd will grow faster at higher temperatures than at lower ones. This aspect is being actively investigated so no recommendations can be made at the present time other than to choose varieties with great care, so they meet the requirements in a scheduled planting scheme.

Broccoli Plant Population

Variation in plant population has only a slight effect on the marketable yield of broccoli. What little increase in yield that occurs is a result of greater plant numbers per acre. Maturity is improved marginally as plant density increases and florets decrease in size and weight. In-row (distance between plants in the row) spacing is the most effective way of achieving an increase in broccoli yield and the resulting smaller florets mature earlier and are more suitable for the fresh market. Close plant spacing is also an effective way of reducing the incidence of hollow stem.

Research in Alberta has shown that a 75 cm (30 in.) between-row spacing accommodates most field equipment. In-row spacing recommendations are:
20 cm (8 in.) between plants - 29,000 plants per acre
15 cm (6 in.) between plants - 34,800 plants per acre

Floret Initiation and Growth in Broccoli

Low temperatures can cause broccoli to produce florets when the plants are at a young physiological stage. The stimulus to produce florets accumulates day by day until the critical level is reached when spear production begins. The stimulus given by low temperature on one day is reduced but not eliminated by subsequent high temperatures on another day.

Spear initiation is influenced by both cultural and environmental conditions. Research has shown that once spear initiation begins, floret development shows a clearly defined response to temperature. Floret diameter increases proportionally to accumulated heat until the floret is mature. What complicates this process is that the base temperature (temperature below which floret growth stops) is different for each variety and increase in floret size may be slower per unit of heat at high plant densities.

Because broccoli is not as sensitive to variations in temperature during spear formation as is cauliflower in curd initiation, fewer problems with this crop have been encountered when schedule planting for a continuous harvest. The production and possible harvesting of secondary spears helps to extend harvest if a subsequent planting is late.

Brussels Sprouts Plant Population

Because of their growth habit, spacing between rows of Brussels sprouts must be wide distances. Trials in Alberta have indicated that the yield of graded medium- and large-sized sprouts increases as the spacing between rows increases. Yield response to distance between plants in the row shows a slight trend toward a higher yield of larger sized sprouts as in-row spacing increases. Maturity is delayed as plant density increases and insect control becomes increasingly difficult. Drop nozzles are required when applying insecticides.

To accommodate and improve the operation of equipment in Brussels sprouts and to maximize yields, the following spacings are recommended:
90 cm (36 in.) between rows, 45 cm (18 in.) between plants - 9,700 plants/acre
90 cm (36 in.) between rows, 60 cm (24 in.) between plants - 7,300 plants/acre

Brussels Sprouts Leaf Removal and Topping

At one time, removal of leaves was believed to encourage sprout development. Research has since proven that the practice is not beneficial and certainly is uneconomic. However, terminal bud removal when bottom sprouts are 2 cm (¾ in.) in diameter promotes earliness and is commonly used in scheduling harvest. Hand topping is labor intensive, so growth regulators have been tested and are now successfully used in the United States as a substitute for manual topping. Chemical topping has never been tested in Alberta.

Harvesting and Handling

Cabbage

Cabbage that is considered ready for harvest generally needs to be firm and of adequate size, at least 15 cm (6 in.) in diameter and about 1.5 kg (3 to 4 lb) in weight. Cabbage is cut by hand with the assistance of picking aides that often accommodate a crew that packs the cabbage into 22.7 kg (50 lb) units, either in green mesh bags or cardboard boxes. Cabbage, when trimmed, should still have 1 to 2 wrapper leaves attached to act as a cushion to prevent bruising during shipment. When packing to meet the 22.7 kg (50 lb) unit requirement, a net weight of 22.7 kg (50 lb) must be met once wrapper leaves are removed, therefore it is always advisable to pack slightly over the 22.7 kg (50 lb) required per unit. Harvested cabbage must be cooled immediately and held in the cooler until shipment. Many early and mid-season varieties lose some color quickly, therefore shipping should not be delayed.

Good winter cabbage varieties retain color even after prolonged storage. Research has shown that cabbage must be cut before it matures for maximum storage life. In this state, the cabbage head still has food reserves left to sustain very slow growth in storage. If a head is mature, there are no food reserves left and consequently death occurs, which is indicated by leaf yellowing and general deterioration. This is why early, fast-growing varieties have poor storage quality characteristics. There is no effective way to accurately indicate when cabbage is mature.

Cabbage frozen in the field should not be harvested until they thaw out naturally. A rapid, artificial indoor thaw results in severe damage. Previously frozen cabbage will require more trimming and should not be stored for a long time.

Cauliflower

Maturity in cauliflower is largely determined by head size. The market prefers a head that measure about 15 cm (6 in.) in diameter. At this size the curd should be pure white and free of a ricey texture, which sometimes is variety related and often a sign of overmaturity.

Fields must be checked daily as cauliflower nears harvest maturity. Once the button (immature head) is visible, leaves must be tied with elastic bands or snapped over the button to keep sunlight off the curd. Until harvest, the rate of head growth is dependent on temperature. Warm days accelerate growth.

Cauliflower is cut by hand and trimmed, so that the stems of the outer wrapper leaves protrude up to meet the lower crown of the head. Picking aides are often used to assist in harvest where wrapping and packing is done in the field. At the same time leaves are tied or snapped to blanch curds scheduled for the next harvest.

Cauliflower is marketed in tray boxes that accommodate either 9, 12 or 16 heads that are of uniform size and whiteness. Size dictates the number of heads that are placed in each box. The market accepts naked heads or heads that are wrapped in a labeled gusset poly bag that is taped to the bottom side of the head. The bag identifies the product, improves the appearance of the head and provides it with some protection during shipping and handling. To preserve freshness, cauliflower must be cooled immediately and kept out of sunlight to retain the white color that is so critical for market. Hydrocooling is an excellent cooling method for removal of field heat from cauliflower before packing naked heads or cello wrapping cauliflower heads. Cauliflower should be marketed soon after harvest. A two-week holding period in a refrigerated cooler is about the maximum storage life that can be expected.

Broccoli

Broccoli heads or spears are ready to harvest when flower buds are still closed and not showing any yellow color. The head must be tight and firm, about 10 cm (4 in.) in diameter. A 15 cm (6 in.) stem should remain attached to each head when cut from the plant. Larger leaves below the head must be removed. Traditionally, 3 to 4 heads of broccoli have been bunched for market, wrapped together by a twistem or elastic band. There is now a trend toward marketing broccoli in single stems, therefore bunching is not required.

Broccoli must be packed into waxed (inside and out) cardboard boxes to yield 14 to 18 bunches weighing 11.3 kg (25 lb), hydrocooled and then topped with a minimum of 2.3 kg (5 lb) of crushed ice or slurry-icing before sealing the box. The market requires broccoli to arrive at the destination with some ice still in the package. Broccoli must be kept refrigerated and moved to market within a few days of harvest because all the ice may melt and florets may open exposing the undesirable yellow color of overmaturity.

Brussels Sprouts

Brussels sprouts are ready for harvest when the majority of spouts on the stem are at least 2.5 cm (1 in.) in diameter. Terminal bud removal promotes earliness if it is done in late August. Stalks may be cut from the root with an axe and stalks run through a de-sprouting machine or de-sprouted manually in the field. Graded sprouts can be hydrocooled and packed 11.3 kg (25 lb) bulk into waxed cardboard boxes and often topped with crushed ice. Brussels sprouts must be held in refrigerated storage before shipment. Sprouts keep better over the long term if they are left attached to the stalk.

Storage

Of all the cole crops, only winter cabbage varieties can be relied upon for long-term storage. Both for the short and long term, a temperature approaching 0° C with 90 per cent relative humidity is required along with good air circulation.

Winter cabbage can be stored in bulk or in pallet bins. Pallet bins have the advantage of improved air circulation plus disease isolation.

In recent years, controlled atmosphere storage (CA) has proven to be beneficial for maintaining good color in storage cabbage which is the major market criterion. CA storage involves the control of the gas concentration of carbon dioxide and oxygen, whereby a low oxygen and a high carbon dioxide concentration restricts respiration in cabbage. Through reduced respiration, color and freshness of cabbage is maintained. This type of storage is more costly and the benefits outweight the extra cost only if 4 to 8 month storage is anticipated.

The Alberta Vegetable Production Guide has specific construction and operation details for refrigerated and controlled-atmosphere storage.

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